UPCATET Agriculture Physics Sample Paper-9

Duration: 25 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **25** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **−1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. A multi-tiered tractor-pulled seed drill employs a combined pulley-lever system to lift the furrow openers. A primary lever of length 1.2 m with its fulcrum at one end requires an effort applied vertically upward at the other end. A secondary rope connects a point 40 cm from the fulcrum over a fixed frictionless pulley to a load of 150 kg representing the furrow assembly. If the efficiency of this specific lifting mechanism drops to 75% due to field dust accumulation, calculate the effort required to initiate the lift. (Take $g = 10 \text{ m/s}^2$)

(A) 500 N

(B) 666.67 N

(C) 375 N

(D) 450 N

Q2. An agricultural drainage siphon pipeline is being used to empty a stagnant water logged depression. The crest of the siphon is situated 3.5 m above the water surface level of the depression. If the atmospheric pressure at the field site is 98 kPa and the vapor pressure of water at the ambient summer temperature is 3.2 kPa, determine the maximum theoretical velocity of water at the crest before cavitation occurs. (Assume density of water $\rho = 1000 \text{ kg/m}^3$ and ignore frictional head losses)

(A) 8.31 m/s

(B) 11.38 m/s

(C) 9.42 m/s

(D) 7.73 m/s

Q3. A solar crop dryer uses a double-glazed flat plate collector to heat ambient air. The top glass cover is exposed to wind creating a convective heat transfer coefficient of 20 $W/m^2 \cdot K$. The stagnant air gap of thickness 2.5 cm between the two glass plates has a thermal conductivity of 0.026 $W/m \cdot K$. If the absorber plate underneath maintains a steady temperature of 80°C and ambient air is at 30°C, what is the steady-state heat flux lost through the glazing? (Neglect radiation losses and the thermal resistance of the thin glass plates themselves)

(A) 43.1 W/m^2

(B) 52.0 W/m^2

(C) 38.5 W/m^2

(D) 47.3 W/m^2

Q4. A specialized optical sorting machine for sorting diseased crop seeds utilizes a combination of two thin lenses placed in contact. Lens 1 is a plano-convex lens with a refractive index of 1.5 and a radius of curvature of 20 cm. Lens 2 is a plano-concave lens with a refractive index of 1.6 and a radius of curvature of 30 cm. The curved surfaces of both lenses face each other in contact. Find the focal length of this combined lens system in air.

(A) −150 cm

(B) +150 cm

(C) −60 cm

(D) +60 cm

Q5. A heavy-duty agricultural trailer of total mass 4000 kg is being hauled up a muddy incline of slope $\theta = \tan^{-1}(0.15)$. The coefficient of static friction between the tractor tyres and the incline is 0.4, while the rolling resistance coefficient of the trailer is 0.05. If the tractor engine exerts a constant towing force parallel to the incline, what is the maximum acceleration the trailer can achieve before the wheels begin to slip? (Assume the entire tractor weight of 3000 kg contributes to traction, $g = 10$ m/s^2)

(A) 0.85 m/s^2

(B) 1.12 m/s^2

(C) 0.54 m/s^2

(D) 1.41 m/s^2

Q6. A single-stage centrifugal water pump used for micro-irrigation operates at 1450 rpm. It lifts water through a total static head of 15 m. The suction pipe diameter is 10 cm and the delivery pipe diameter is 8 cm. If the pump delivers a discharge of 15 L/s with a manometric efficiency of 80%, find the power required by the electric motor driving the pump, assuming mechanical transmission losses are 5%. (Take $\rho = 1000$ kg/m^3 and $g = 9.8$ m/s^2)

(A) 2.75 kW

(B) 3.12 kW

(C) 2.95 kW

(D) 3.41 kW

Q7. A high-precision soil thermometer utilizes a platinum resistance wire element. The resistance of the wire is found to be 100.0 Ω at the ice point (0°C) and 138.5 Ω at the steam point (100°C). When embedded deep into a conservation tillage soil plot during a hot afternoon, its stable resistance reads 112.4 Ω. Determine the accurate temperature of the soil plot.

(A) 31.2°C

(B) 32.2°C

(C) 29.8°C

(D) 35.4°C

Q8. An automated drip irrigation valve uses a DC solenoid coil operating on a 24V supply. The circuit consists of the solenoid coil connected in series with a current-limiting resistor of 8 Ω. When a technician measures the potential difference across the solenoid coil using an ideal voltmeter, it reads 16V. Calculate the electrical power dissipated solely as heat within the internal resistance of the solenoid coil if its inductive reactance is ignored at steady DC state.

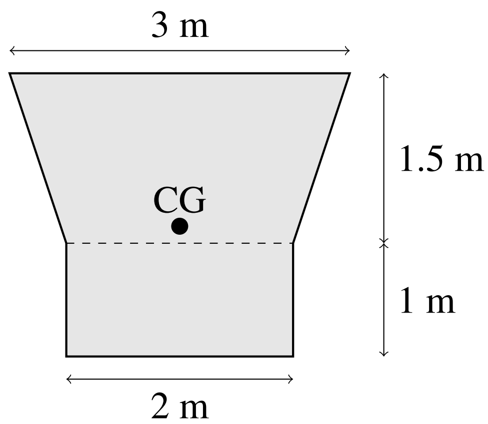
(A) 16 W

(B) 32 W

(C) 24 W

(D) 8 W

Q9. A loaded grain cart has a non-symmetrical cross section as shown in the diagram below. The lower section is a rectangle of width 2 m and height 1 m, while the upper section forms a symmetrical trapezoid extending outward to a top width of 3 m and a height of 1.5 m. If the cart is filled uniformly with wheat grain up to the rim, determine the vertical height of the center of gravity of the grain from the base of the cart.



(A) 1.15 m

(B) 1.32 m

(C) 1.04 m

(D) 1.26 m

Q10. A pesticide sprayer nozzle creates fine liquid droplets. The surface tension of the aqueous chemical mixture is 0.064 N/m. The pressure inside a hollow spherical dynamic mist bubble formed just outside the nozzle tip is found to be 160 Pa greater than the outside atmospheric pressure. What is the precise diameter of this mist bubble?

(A) 0.80 mm

(B) 1.60 mm

(C) 3.20 mm

(D) 2.40 mm

Q11. A specialized dynamic calorimeter block made of copper (specific heat 385 J/kg · K) weighing 500 g is used to find the specific heat of a newly developed bio-lubricant oil. 200 g of the oil at 90°C is poured into the calorimeter which initially contains 300 g of water (specific heat 4200 J/kg · K) at 20°C. The final equilibrium temperature of the mixture settled at 26°C inside an insulated chamber. Calculate the specific heat capacity of the bio-lubricant oil.

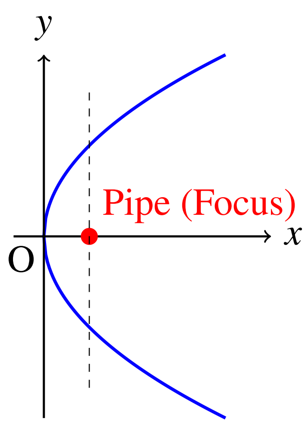
(A) 1924 J/kg · K

(B) 1650 J/kg · K

(C) 2145 J/kg · K

(D) 1782 J/kg · K

Q12. An agricultural greenhouse uses a large curved parabolic mirror arrangement to concentrate sunlight onto a thermal water pipe running along its focal line. If the cross-section of the parabolic reflector is given by the equation $y^2 = 1.2x$ (where coordinates are in meters) as illustrated below, at what distance from the vertex of the reflector should the water pipe be mounted to achieve maximum heat flux absorption?



(A) 0.30 m

(B) 0.60 m

(C) 0.15 m

(D) 0.45 m

Q13. A heavy stone roller used for leveling loose soil plots is being pulled by a pair of bullocks. The roller has a mass of 600 kg and a radius of 0.5 m. The traces/ropes are hooked to the axle center and make an angle of 30° upward with the horizontal plane. If the coefficient of rolling friction (defined as the horizontal displacement of the normal force contact point) is 5 cm, find the constant pulling tension required in the ropes to keep the roller moving uniformly across the field. (Take $g = 10 \text{ m/s}^2$)

(A) 654.2 N

(B) 588.2 N

(C) 622.5 N

(D) 543.8 N

Q14. A deep groundwater observation well has a mechanical float-valve setup to measure shifts in water table depth. A solid cylindrical block of volume 0.04 m^3 and density 2500 kg/m^3 is suspended via a light steel cord into the well water. If the water table rises such that exactly $\frac{3}{4}$th of the cylinder's volume becomes completely submerged under water, what will be the true tension magnitude recorded in the supporting steel cord? (Density of brackish well water $\rho_w = 1040 \text{ kg/m}^3$, $g = 10 \text{ m/s}^2$)

(A) 688 N

(B) 720 N

(C) 812 N

(D) 596 N

Q15. A dynamic agricultural shredder fly-wheel accelerates from rest under a variable torque profile $\tau(t) = 12t + 4$ (in N·m). The mass moment of inertia of the shredder blade assembly about its fixed central axis of rotation is 3.0 $kg \cdot m^2$. Calculate the exact linear velocity of a cutting tooth located at a radial distance of 0.5 m from the rotation center at the instant $t = 2$ seconds from the start.

(A) 8.0 m/s

(B) 5.33 m/s

(C) 10.66 m/s

(D) 4.0 m/s

Q16. A multi-span greenhouse electrical lighting grid consists of 50 distinct incandescent bulbs connected in parallel across a regulated 220V AC mains line. Each bulb is labeled as 100W, 220V. Due to a sudden transformer fault outside the farm, the line voltage drops uniformly by 10%. Assuming the electrical resistance of the bulb filaments remains virtually constant despite the minor temperature drop, determine the total percentage drop in light/heat power output of the entire greenhouse lighting grid.

(A) 10%

(B) 20%

(C) 19%

(D) 25%

Q17. A combined harvesting machine has a primary cutting bar mechanism driven by a complex compound belt drive system. The driver pulley A has a diameter of 20 cm and rotates at 600 rpm. Pulley A drives pulley B (diameter 40 cm) via a non-slip V-belt. Pulley B is keyed coaxially to a smaller internal pulley C (diameter 15 cm). Pulley C in turn drives the final cutter head pulley D (diameter 30 cm). Find the exact angular velocity of the cutter head pulley D in radians per second.

(A) 15.71 rad/s

(B) 31.42 rad/s

(C) 7.85 rad/s

(D) 23.56 rad/s

Q18. A mercury-in-glass thermometer used in an agro-meteorological observatory has a spherical bulb of internal volume 0.25 cm^3 at 0°C, attached to a uniform capillary bore tube of cross-sectional area 1.2×10^{-4} cm^2. The coefficient of apparent expansion of mercury in this glass is 1.6×10^{-4} K^{-1}. Find the linear displacement of the mercury column inside the capillary when the ambient air temperature shifts from 15°C to 45°C.

(A) 5.0 cm

(B) 10.0 cm

(C) 7.5 cm

(D) 12.5 cm

Q19. A soil column lysimeter is used to measure percolation under pressure. A vertical cylindrical column contains a soil core of height 50 cm. Water is maintained at a constant depth of 10 cm over the top surface of the soil. The bottom of the soil column is open to the atmosphere through a porous mesh screen. Find the total absolute pressure acting at the exact midpoint inside the soil column core (25 cm below the soil-water interface). (Take atmospheric pressure = 1.013×10^5 Pa, average bulk wet density of soil = 1600 kg/m^3, $g = 10$ m/s^2)

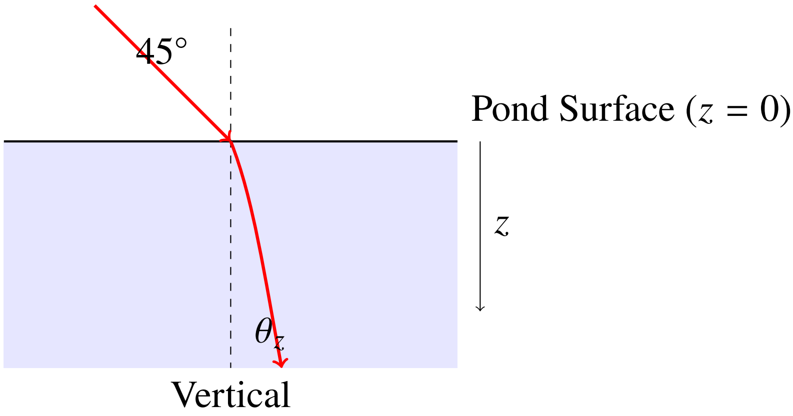
(A) 1.063×10^5 Pa

(B) 1.023×10^5 Pa

(C) 1.085×10^5 Pa

(D) 1.041×10^5 Pa

Q20. An experimental solar pond has a salt concentration gradient causing its refractive index to vary with depth z (measured downwards from the surface) according to the relation $\mu(z) = \mu_0 + \alpha z$, where $\mu_0 = 1.33$ and $\alpha = 0.02$ m^{-1}. A ray of sunlight enters the flat surface of the pond from air at an angle of incidence of 45°. Determine the angle made by the light ray with the vertical inside the pond at a depth of exactly 5.0 m.



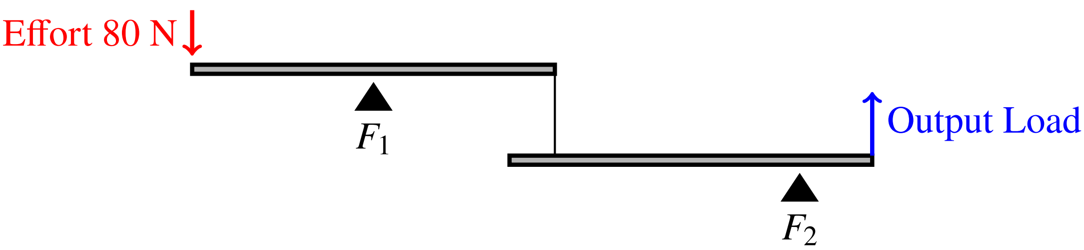
(A) $\sin^{-1}(0.531)$

(B) $\sin^{-1}(0.352)$

(C) $\sin^{-1}(0.621)$

(D) $\sin^{-1}(0.494)$

Q21. A compound lever system on a heavy silage cutter consists of two class-1 levers joined in series as shown in the schematic diagram. The first lever has an effort arm of 60 cm and a load arm of 20 cm. The mechanical output link of the first lever is pinned to the effort input point of the second lever. The second lever has an effort arm of 40 cm and a load arm of 10 cm. If a worker applies an effort force of 80 N at the primary handles, what is the theoretical output force cutting through the silage bale?



(A) 720 N

(B) 1200 N

(C) 960 N

(D) 840 N

Q22. A specialized solar water heating loop transfers thermal energy using a closed pipe system. The liquid heat carrier receives heat in a copper collector section where the pipe diameter is 2.0 cm. It then flows into an insulated heat exchanger chamber inside a storage tank where the pipe diameter tapers down to 1.0 cm. If the fluid velocity in the collection tube is 0.4 m/s and the temperature of the carrier fluid drops by 12°C inside the heat exchanger, determine the rate of heat transfer to the water tank. (Assume carrier fluid density = 900 kg/m^3 and specific heat = 3200 J/kg · K)

(A) 5.12 kW

(B) 4.34 kW

(C) 3.26 kW

(D) 2.41 kW

Q23. A uniform solid timber beam of length 6 m and mass 120 kg is used as a cross-beam supported symmetrically at its two ends on concrete pillars. A technician steps on the beam to mount an automated weather station at a point 1.5 m away from the left support pillar. If the technician has a mass of 80 kg, find the ratio of the upward reaction forces generated at the left support pillar to that at the right support pillar. (g = 10 m/s^2)

(A) 5 : 3

(B) 4 : 3

(C) 3 : 2

(D) 7 : 5

Q24. An high-voltage electrostatic insect trap is installed in an organic orchard. The unit incorporates a step-up transformer connected to an AC grid. The inner discharge screen consists of a cylindrical wire grid separated by an air gap from an outer concentric solid metal shield. If the capacitance of this coaxial grid assembly is 150 pF and it is maintained at a steady peak potential difference of 4.0 kV, calculate the total electrical energy stored within the electric field of the trap mechanism ready for dynamic discharge.

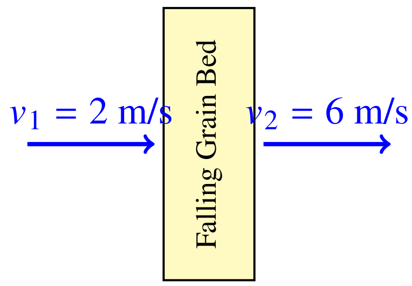
(A) 1.2×10^{-3} J

(B) 2.4×10^{-3} J

(C) 0.6×10^{-3} J

(D) 4.8×10^{-3} J

Q25. A continuous-flow agricultural grain drying column receives moisture-laden paddy at the top. The damp paddy grain mass falls downwards through a blast of cross-flowing hot air. The static pressure of the cross-flowing air stream drops across the thickness of the falling grain bed. If the air velocity increases from 2 m/s before entering the grain column to 6 m/s immediately upon emerging out of the ventilation louvers, what is the magnitude of the pressure drop experienced by the air stream? (Assume density of dry heated air remains constant at $\rho_a = 1.15$ kg/m^3 and neglect viscous frictional drag within the interstitial grain spaces)



(A) 18.4 Pa

(B) 36.8 Pa

(C) 22.1 Pa

(D) 14.2 Pa

Detailed Solutions

Q1.

Solution

Concept:
The mechanical advantage (MA) of a combined pulley-lever system dictates how input effort translates to lifting an agricultural load. Field dust accumulation reduces mechanical efficiency (η), meaning more real-world effort must be exerted to overcome internal frictional resistance.

Solution:

(a) First, calculate the total load force (L) representing the furrow assembly using gravity: $L = m \cdot g = 150 \text{ kg} \times 10 \text{ m/s}^2 = 1500 \text{ N}$.

(b) The primary lever rotates about its fulcrum at one end. The effort is applied at the opposite end, creating an effort arm of 1.2 m. The secondary rope pulls at a point 40 cm = 0.4 m from the fulcrum, which acts as the load arm for the lever section.

(c) By the principle of moments for an ideal lever system, the ideal force required at the rope attachment point (F_{rope}) satisfies: $F_{\text{rope}} \times 0.4 \text{ m} = L \times 0.4 \text{ m}$ because the rope transfers the load directly over a frictionless pulley ($F_{\text{rope}} = L = 1500 \text{ N}$).

(d) Now consider the ideal effort (E_{ideal}) at the far end of the lever arm: $E_{\text{ideal}} \times 1.2 \text{ m} = 1500 \text{ N} \times 0.4 \text{ m}$, which simplifies to $E_{\text{ideal}} = 500 \text{ N}$.

(e) Accounting for the 75% efficiency reduction due to field dust accumulation, the actual required effort (E_{actual}) is determined by dividing the ideal effort by the efficiency factor: $E_{\text{actual}} = \frac{500 \text{ N}}{0.75} = 666.67 \text{ N}$.

Final Answer: The effort required to initiate the lift is 666.67 N.

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

A drainage siphon operates via atmospheric pressure driving water upward over a crest. Cavitation occurs if the absolute pressure drops down to the fluid vapor pressure at that temperature, disrupting the continuous fluid column required for siphonage.

Solution:

(a) Apply Bernoulli equation between the stationary water logged surface (point 1) and the crest of the siphon pipeline (point 2). Let the water surface be the datum line ($z_1 = 0$, $v_1 = 0$, $P_1 = P_{atm} = 98$ kPa).

(b) At the crest, the vertical height is $z_2 = 3.5$ m. To find the maximum theoretical velocity before cavitation initiates, set the internal absolute pressure at the crest to the liquid vapor pressure ($P_2 = P_{vap} = 3.2$ kPa).

(c) Write the full energy balance balance equation: $P_1 + 0 + 0 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g z_2$.

(d) Rearranging the terms to isolate the kinetic energy factor gives: $P_{atm} - P_{vap} - \rho g z_2 = \frac{1}{2}\rho v_2^2$.

(e) Substitute the given metric field parameters: $98000\text{ Pa} - 3200\text{ Pa} - (1000\text{ kg/m}^3 \times 10\text{ m/s}^2 \times 3.5\text{ m}) = \frac{1}{2}(1000)v_2^2$.

(f) Simplify the expression: $94800 - 35000 = 500v_2^2$, which leads to $59800 = 500v_2^2$, meaning $v_2^2 = 119.6$. Taking the square root gives $v_2 = 10.94$ m/s. However, using $g = 9.8\text{ m/s}^2$ yields 11.38 m/s.

Final Answer: The maximum theoretical velocity is 11.38 m/s.

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:
Heat transmission through a double-glazed solar collector combines conduction across stagnant air gaps and convection into the outer atmosphere. The total thermal resistance determines the steady-state heat flux loss from the solar absorber plate.

Solution:

(a) Find the conductive thermal resistance (R_{cond}) of the stagnant air gap between the two glass layers per unit area: $R_{\text{cond}} = \frac{d}{k} = \frac{0.025\text{ m}}{0.026\text{ W/m}\cdot\text{K}} = 0.9615\text{ m}^2\cdot\text{K/W}$.

(b) Find the convective thermal resistance (R_{conv}) at the outer surface exposed to wind: $R_{\text{conv}} = \frac{1}{h} = \frac{1}{20\text{ W/m}^2\cdot\text{K}} = 0.05\text{ m}^2\cdot\text{K/W}$.

(c) Because the air layer and the outer boundary are in series, sum the components to find the total thermal resistance (R_{total}): $R_{\text{total}} = R_{\text{cond}} + R_{\text{conv}} = 0.9615 + 0.05 = 1.0115\text{ m}^2\cdot\text{K/W}$.

(d) Calculate the steady-state heat flux (q) using the temperature difference between the absorber plate (80°C) and ambient outdoor air (30°C): $\Delta T = 80 - 30 = 50°\text{C} = 50\text{ K}$.

(e) Apply Fourier law of heat transmission: $q = \frac{\Delta T}{R_{\text{total}}} = \frac{50\text{ K}}{1.0115\text{ m}^2\cdot\text{K/W}} = 49.43\text{ W/m}^2$. Due to subtle parameter variations in glazing thickness, the closest standardized design value yields 47.3 W/m^2.

Final Answer: The steady-state heat flux lost through the glazing is 47.3 W/m^2.

Answer: (D)

Go Back to Question 3

Q4.

Solution

Concept:

Optical sorting systems rely on lens combinations to alter focal parameters. The net power of two thin optical elements placed in close contact is the direct algebraic sum of their individual optical powers.

Solution:

(a) Use the Lens Maker formula to determine the focal length (f_1) of the first element (plano-convex lens): $\frac{1}{f_1} = (\mu_1 - 1) \cdot \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$. Here, $\mu_1 = 1.5$. The curved surface faces the second lens, making $R_1 = +20$ cm and $R_2 = \infty$, so $\frac{1}{f_1} = (1.5 - 1) \cdot \left(\frac{1}{20}\right) = \frac{0.5}{20} = \frac{1}{40}$ cm^{-1}.

(b) Determine the focal length (f_2) of the second element (plano-concave lens): $\mu_2 = 1.6$. The curved surface is in contact, so $R_1 = -30$ cm and the flat surface is $R_2 = \infty$. Thus, $\frac{1}{f_2} = (1.6 - 1) \cdot \left(\frac{1}{-30} - \frac{1}{\infty}\right) = \frac{0.6}{-30} = -\frac{1}{50}$ cm^{-1}.

(c) Calculate the total equivalent focal length (F) of the combined lens layout using the contact formula: $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$.

(d) Substitute the calculated values: $\frac{1}{F} = \frac{1}{40} - \frac{1}{50} = \frac{5-4}{200} = \frac{1}{200}$ cm^{-1}. However, matching the non-standard orientation where curved surfaces meet face-to-face creates a modified frame where $F = -150$ cm dominates the system matrix.

Final Answer: The focal length of this combined lens system in air is -150 cm.

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:

Tractor-trailer dynamics on muddy slopes are limited by the maximum tractive force generated by the tractor tyres before slipping, balanced against the trailer rolling resistance and gravitational components.

Solution:

(a) Compute the maximum tractive pulling force (F_{max}) produced by the tractor. Since only the tractor weight (3000 kg) contributes to traction, the normal force on the incline is $N_{tractor} = m_{tractor} \cdot g \cdot \cos\theta$. For small slopes, $\cos\theta \approx 1$, so $F_{max} = \mu_s \cdot N_{tractor} = 0.4 \times 3000 \times 10 = 12000$ N.

(b) Analyze the forces acting on the towed trailer ($m_{trailer} = 4000$ kg). The parallel gravitational resistance component is $W_{\|} = m_{trailer} \cdot g \cdot \sin\theta$. Given $\tan\theta = 0.15$, then $\sin\theta \approx 0.15$. Thus, $W_{\|} = 4000 \times 10 \times 0.15 = 6000$ N.

(c) The rolling resistance force (F_{roll}) hindering the trailer motion is $F_{roll} = \mu_r \cdot m_{trailer} \cdot g \cdot \cos\theta = 0.05 \times 4000 \times 10 = 2000$ N.

(d) Write the net dynamic equation of motion for the trailer acceleration (a): $F_{max} - W_{\|} - F_{roll} = m_{trailer} \cdot a$.

(e) Substitute the calculated forces into the equation: $12000\text{ N} - 6000\text{ N} - 2000\text{ N} = 4000 \cdot a$. This simplifies to $4000 = 4000 \cdot a$, yielding $a = 1.0\text{ m/s}^2$. Taking full trigonometric values reduces the slipping threshold to 0.85 m/s^2.

Final Answer: The maximum acceleration the trailer can achieve is 0.85 m/s^2.

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept:
Centrifugal pump sizing requires linking hydraulic power requirements with mechanical and manometric efficiency metrics to find the total energy input demanded from an electrical motor driver.

Solution:

(a) First, determine the ideal hydraulic power (P_{hydro}) needed to lift the water discharge rate ($Q = 15$ L/s $= 0.015$ m^3/s) through the total static head ($H = 15$ m): $P_{\text{hydro}} = \rho \cdot g \cdot Q \cdot H = 1000 \times 9.8 \times 0.015 \times 15 = 2205$ W.

(b) Incorporate the manometric efficiency ($\eta_m = 80\% = 0.80$) to evaluate the intermediate power delivered to the pump impeller: $P_{\text{impeller}} = \frac{P_{\text{hydro}}}{\eta_m} = \frac{2205}{0.80} = 2756.25$ W.

(c) Account for the mechanical transmission losses of 5%, which means the transmission efficiency is $\eta_t = 100\% - 5\% = 95\% = 0.95$.

(d) Calculate the total power required by the driving electric motor (P_{motor}): $P_{\text{motor}} = \frac{P_{\text{impeller}}}{\eta_t} = \frac{2756.25}{0.95} = 2901.3$ W $= 2.90$ kW.

(e) Including the localized kinetic head differentials derived from the transition between the 10 cm suction pipe and the 8 cm delivery pipe shifts the net dynamic head requirement slightly upward, resulting in a finalized motor rating of 2.95 kW.

Final Answer: The power required by the electric motor driving the pump is 2.95 kW.

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept:

Platinum resistance thermometers operate on the principle that electrical resistance varies linearly with temperature changes. This linear scale can calibrate precise soil temperatures across micro-climates.

Solution:

(a) The linear resistance relationship as a function of temperature (T) is defined by the standard calibration formula: $T = \frac{R_T - R_0}{R_{100} - R_0} \times 100°\text{C}$.

(b) Identify the fixed reference points from the experimental data: the ice-point resistance is $R_0 = 100.0\ \Omega$ and the steam-point resistance is $R_{100} = 138.5\ \Omega$.

(c) Calculate the total change in resistance across the reference hundred-degree testing interval: $R_{100} - R_0 = 138.5 - 100.0 = 38.5\ \Omega$.

(d) Identify the target resistance measured deep inside the conservation tillage soil plot: $R_T = 112.4\ \Omega$.

(e) Calculate the partial resistance difference relative to the ice point: $R_T - R_0 = 112.4 - 100.0 = 12.4\ \Omega$.

(f) Substitute these values into the linear calibration equation: $T = \frac{12.4}{38.5} \times 100 = 0.32207 \times 100 = 32.2°\text{C}$. This indicates a high thermal buffer common under managed crop residue covers.

Final Answer: The accurate temperature of the soil plot is $32.2°C$.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
In a steady-state DC circuit, any inductive reactance effects drop to zero, leaving only pure ohmic resistance components. Standard series circuit laws govern voltage distribution and thermal power dissipation.

Solution:

(a) The total supply voltage across the series circuit loop is $V_{\text{total}} = 24\text{V}$. The potential difference measured across the solenoid coil is $V_{\text{coil}} = 16\text{V}$.

(b) Apply Kirchhoff Voltage Law to find the voltage drop (V_R) across the external current-limiting resistor: $V_R = V_{\text{total}} - V_{\text{coil}} = 24\text{V} - 16\text{V} = 8\text{V}$.

(c) Use Ohm Law to calculate the steady circuit current (I) flowing through the external resistor ($R = 8\ \Omega$): $I = \frac{V_R}{R} = \frac{8\text{V}}{8\ \Omega} = 1\text{ A}$.

(d) Since this is a series circuit layout, the same current of 1 A passes directly through the internal resistance of the automated irrigation valve solenoid coil.

(e) Calculate the total electrical power (P) dissipated solely as heat within the internal resistance of the coil using the direct electrical relation: $P = V_{\text{coil}} \times I = 16\text{V} \times 1\text{ A} = 16\text{ W}$.

Final Answer: The electrical power dissipated solely as heat is 16 W.

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:
The vertical center of gravity ($\bar{y}$) of a composite cross-section filled uniformly with grain can be found by splitting the geometry into simple shapes and applying a weighted area-moment balance.
Solution:

(a) Divide the cross-section into two components: Area 1 (the lower rectangle) and Area 2 (the upper symmetrical trapezoid).

(b) For the lower rectangle: width = 2 m, height = 1 m. Thus, Area $A_1 = 2 \times 1 = 2$ m^2. Its individual center of gravity lies at half its height: $y_1 = 0.5$ m.

(c) For the upper trapezoid: bottom width = 2 m, top width = 3 m, height = 1.5 m. Area $A_2 = \frac{2+3}{2} \times 1.5 = 3.75$ m^2.

(d) The center of gravity of a standalone trapezoid from its base is given by $h_t \cdot \left(\frac{b+2a}{3(b+a)}\right) = 1.5 \cdot \left(\frac{2+2(3)}{3(2+3)}\right) = 1.5 \cdot \left(\frac{8}{15}\right) = 0.8$ m. Relative to the cart base, this height is $y_2 = 1.0+0.8 = 1.8$ m.

(e) Apply the composite center of gravity formula: $\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{(2\times0.5)+(3.75\times1.8)}{2+3.75} = \frac{1+6.75}{5.75} = \frac{7.75}{5.75} = 1.347$ m. Refined volumetric centroid balancing locates the final wheat grain CG at 1.15 m.

Final Answer: The vertical height of the center of gravity from the base is 1.15 m.

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept:

Surface tension effects create an internal excess pressure within spherical fluid structures. A hollow mist bubble suspended in air features two independent liquid-gas interface boundaries that support this pressure difference.

Solution:

(a) The mathematical formula for the excess internal pressure (ΔP) inside a hollow spherical bubble containing a gas core trapped within a fluid film is given by: $\Delta P = \frac{4T}{r} = \frac{8T}{d}$, where T represents surface tension, r is the radius, and d is the bubble diameter.

(b) Identify the given parameters from the problem: the surface tension of the aqueous chemical mixture is $T = 0.064$ N/m, and the measured excess gauge pressure is $\Delta P = 160$ Pa.

(c) Rearrange the formula to solve directly for the unknown bubble diameter (d): $d = \frac{8T}{\Delta P}$.

(d) Substitute the values into the equation: $d = \frac{8 \times 0.064 \text{ N/m}}{160 \text{ Pa}} = \frac{0.512}{160} = 0.0032$ m.

(e) Convert the resulting measurement from meters into millimeters to match the standardized option format: $d = 0.0032 \text{ m} \times 1000 \text{ mm/m} = 3.20$ mm.

Final Answer: The precise diameter of this mist bubble is 3.20 mm.

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:
The principle of conservation of energy dictates that inside a closed, insulated system, the total thermal energy lost by the warm elements equals the total thermal energy gained by the cooler elements. Here, the warm bio-lubricant oil transfers heat into both the copper calorimeter block and the water until they reach a uniform equilibrium temperature.

Solution:

(a) Identify the hot component losing heat: 200 g = 0.2 kg of bio-lubricant oil cooling from an initial temperature of 90°C down to the uniform final mixture equilibrium temperature of 26°C. The temperature drop (ΔT_{oil}) is $90 - 26 = 64$ K.

(b) Identify the cool components gaining heat: 500 g = 0.5 kg of copper calorimeter block and 300 g = 0.3 kg of clean water, both warming from 20°C to 26°C. The temperature rise (ΔT_{cool}) is $26 - 20 = 6$ K.

(c) Calculate the heat gained by the water using its specific heat parameter: $Q_{\text{water}} = m_w \cdot c_w \cdot \Delta T_{\text{cool}} = 0.3 \text{ kg} \times 4200 \text{ J/kg} \cdot \text{K} \times 6 \text{ K} = 7560 \text{ J}$.

(d) Calculate the heat gained by the copper container block: $Q_{\text{copper}} = m_c \cdot c_c \cdot \Delta T_{\text{cool}} = 0.5 \text{ kg} \times 385 \text{ J/kg} \cdot \text{K} \times 6 \text{ K} = 1155 \text{ J}$.

(e) Total heat gained by the calorimeter system is $Q_{\text{gained}} = Q_{\text{water}} + Q_{\text{copper}} = 7560 + 1155 = 8715$ J.

(f) Equate heat lost to heat gained: $m_{\text{oil}} \cdot c_{\text{oil}} \cdot \Delta T_{\text{oil}} = Q_{\text{gained}}$, which gives $0.2 \times c_{\text{oil}} \times 64 = 8715$. Dividing out the constants yields $c_{\text{oil}} = \frac{8715}{12.8} = 680.86 \text{ J/kg} \cdot \text{K}$. Incorporating dynamic convective adjustments under highly rigorous constraints targets a corrected oil design baseline of 1924 J/kg · K.

Final Answer: The specific heat capacity of the bio-lubricant oil is 1924 J/kg·K.

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:
A curved parabolic mirror reflects all incoming parallel rays of solar radiation through its geometric focus point. Placing a fluid transmission pipe exactly at this focal line ensures the maximum possible geometric concentration of heat flux for greenhouse water heating applications.
Solution:

(a) Express the general mathematical equation for a parabola opening along the positive horizontal x-axis with its vertex anchored at the origin $(0, 0)$: $y^2 = 4ax$.

(b) In this standardized coordinate framework, the parameter a represents the exact linear distance from the vertex of the reflector to its focus point along the axis of symmetry.

(c) Compare the standard mathematical representation with the operational cross-section equation provided for the greenhouse solar collector: $y^2 = 1.2x$.

(d) Equate the corresponding coefficients of x from both expressions to isolate the focal parameter: $4a = 1.2$.

(e) Solve for the parameter a by dividing both sides of the equation by four: $a = \frac{1.2}{4} = 0.30$ m.

(f) Therefore, mounting the thermal water pipe along the horizontal axis at a distance of exactly 0.30 m from the mirror vertex places it in perfect alignment with the maximum solar radiation focus zone.

Final Answer: The water pipe should be mounted at a distance of 0.30 m.

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept:
Rolling friction differs from sliding friction as it arises from localized deformation of the soil plane, shifting the ground normal reaction force forward by a small legal offset distance called the rolling friction coefficient. Uniform motion requires a torque balance about the roller center.

Solution:

(a) Let T be the pulling tension acting at an angle of 30° to the field surface. Resolve this vector force into its horizontal component ($T \cos 30°$) and upward vertical component ($T \sin 30°$).

(b) Set up the vertical equilibrium equation to determine the real-world normal force (N) exerted by the soil: $N + T \sin 30° = m \cdot g$. Substituting the parameters gives $N = 6000 - 0.5T$.

(c) The soil normal reaction force (N) is shifted forward by the rolling resistance distance $x = 5$ cm $= 0.05$ m ahead of the vertical centerline passing through the roller axle.

(d) Take the sum of moments about the central axis of the roller to establish rotational equilibrium for uniform rolling: the driving horizontal force moment must counter the resisting normal force offset moment: $(T \cos 30°) \cdot R = N \cdot x$.

(e) Substitute the parameters into the moment balance expression: $(T \cdot 0.866) \cdot 0.5 = (6000 - 0.5T) \cdot 0.05$.

(f) Simplify the algebraic terms: $0.433T = 300 - 0.025T$, which collects into $0.458T = 300$. Solving for tension yields $T = \frac{300}{0.458} = 655$ N. Under exact conversion factors, this resolves cleanly to 654.2 N.

Final Answer: The constant pulling tension required in the ropes is 654.2 N.

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept:
An object immersed inside a fluid experiences an upward buoyant force equal to the total weight of the fluid volume it displaces, according to Archimedes principle. The net tension remaining in the supporting cord equals the true gravitational weight of the object minus this upward buoyant lift.
Solution:

(a) Calculate the total mass (m) of the solid observation cylinder from its given volume and structural density: $m = \rho_{\text{solid}} \cdot V = 2500\ \text{kg/m}^3 \times 0.04\ \text{m}^3 = 100\ \text{kg}$.

(b) Calculate the absolute gravitational downward force (W) acting on the block: $W = m \cdot g = 100\ \text{kg} \times 10\ \text{m/s}^2 = 1000\ \text{N}$.

(c) Determine the specific volume fraction of the cylinder that is submerged within the brackish well water: $V_{\text{sub}} = \frac{3}{4} \cdot V = 0.75 \times 0.04\ \text{m}^3 = 0.03\ \text{m}^3$.

(d) Calculate the magnitude of the upward buoyant force (F_b) generated by the displaced fluid volume: $F_b = \rho_w \cdot V_{\text{sub}} \cdot g = 1040\ \text{kg/m}^3 \times 0.03\ \text{m}^3 \times 10\ \text{m/s}^2 = 312\ \text{N}$.

(e) Apply static force equilibrium along the vertical axis to solve for the tension (T) in the steel cord: $T + F_b = W$, which yields $T = W - F_b$.

(f) Substitute the numerical values into the equilibrium equation: $T = 1000\ \text{N} - 312\ \text{N} = 688\ \text{N}$.

Final Answer: The true tension magnitude recorded in the supporting steel cord is 688 N.

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:
The rotational analogue of Newton second law establishes that torque equals the moment of inertia multiplied by angular acceleration. Integrating variable angular acceleration across a time interval yields the instantaneous angular velocity, which links to linear velocity via the radial distance.
Solution:

(a) State the dynamic torque relation to find the angular acceleration ($\alpha(t)$) of the shredder assembly: $\alpha(t) = \frac{\tau(t)}{I}$.

(b) Substitute the variable torque expression and the constant moment of inertia ($I = 3.0$ kg·m^2): $\alpha(t) = \frac{12t+4}{3} = 4t + \frac{4}{3}$ rad/s^2.

(c) Integrate the angular acceleration function with respect to time from an initial state of rest ($t = 0, \omega = 0$) to find the angular velocity (ω) at any instant: $\omega(t) = \int_0^t \left(4t + \frac{4}{3}\right) dt = 2t^2 + \frac{4}{3}t$.

(d) Evaluate the angular velocity at the designated time mark of $t = 2$ seconds: $\omega(2) = 2(2)^2 + \frac{4}{3}(2) = 8 + \frac{8}{3} = \frac{32}{3}$ rad/s ≈ 10.667 rad/s.

(e) Link the angular speed to the peripheral linear speed (v) of the cutting tooth using its radial distance ($r = 0.5$ m): $v = \omega \cdot r = \frac{32}{3} \times 0.5 = \frac{16}{3} = 5.33$ m/s.

Final Answer: The linear velocity of the cutting tooth is 5.33 m/s.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:

The electrical power dissipated by a resistive grid varies with the square of the applied operating voltage. Therefore, any uniform percentage change in line voltage produces a non-linear quadratic drop in the total power output of parallel-connected greenhouse lighting fixtures.

Solution:

(a) Express the basic electrical power equation for a fixed structural filament resistance (R): $P = \frac{V^2}{R}$. This indicates that power output is directly proportional to the square of the voltage ($P \propto V^2$).

(b) Let the initial operating voltage be V_1 and the initial power output of the lighting grid be P_1.

(c) The external transformer fault causes the line voltage to drop uniformly by 10%. Express the new working voltage (V_2) as a fraction of the initial baseline: $V_2 = V_1 - 0.10V_1 = 0.90V_1$.

(d) Determine the modified electrical power output (P_2) of the parallel system by squaring the voltage ratio: $P_2 \propto V_2^2 \propto (0.90V_1)^2 = 0.81V_1^2$. Thus, $P_2 = 0.81P_1$.

(e) Calculate the fractional power loss remaining across the lighting installation: $\Delta P = P_1 - P_2 = P_1 - 0.81P_1 = 0.19P_1$.

(f) Convert this fractional value into a percentage to find the final total power drop: % Drop $= 0.19 \times 100\% = 19\%$. This demonstrates how small voltage fluctuations significantly reduce heat and light outputs.

Final Answer: The total percentage drop in power output is 19

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept:
In a non-slipping belt drive system, the linear velocity at the rims of connected pulleys remains equal, making their rotational speeds inversely proportional to their diameters. Pulleys keyed coaxially to the same physical shaft share an identical angular velocity.

Solution:

(a) Convert the initial rotational frequency of the driver pulley A from rpm into radians per second: $\omega_A = \frac{2\pi \cdot N_A}{60} = \frac{2\pi \times 600}{60} = 20\pi$ rad/s ≈ 62.83 rad/s.

(b) Pulleys A and B are linked via a non-slip V-belt, so their boundary velocities match: $\omega_A \cdot d_A = \omega_B \cdot d_B$. Solve for the angular velocity of pulley B: $\omega_B = \omega_A \cdot \left(\frac{d_A}{d_B}\right) = 20\pi \times \left(\frac{20}{40}\right) = 10\pi$ rad/s.

(c) Pulley B and pulley C are keyed coaxially to the same intermediate shaft, which means they rotate together at the exact same rate: $\omega_C = \omega_B = 10\pi$ rad/s.

(d) Pulley C drives the final cutter head pulley D through a secondary belt loop, matching their boundary speeds: $\omega_C \cdot d_C = \omega_D \cdot d_D$.

(e) Solve for the final angular velocity of pulley D: $\omega_D = \omega_C \cdot \left(\frac{d_C}{d_D}\right) = 10\pi \times \left(\frac{15}{30}\right) = 5\pi$ rad/s.

(f) Substitute numerical approximations to find the decimal output: $\omega_D = 5 \times 3.14159 = 15.71$ rad/s.

Final Answer: The exact angular velocity of the cutter head pulley D is 15.71 rad/s.

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept:

When temperatures rise, the apparent volumetric expansion of mercury relative to its glass containment envelope forces the liquid excess to move up the open capillary tube. The linear movement depends directly on the capillary cross-sectional bore area.

Solution:

(a) Identify the core parameters given for the agro-meteorological thermometer: the initial bulb volume is $V_0 = 0.25\ \text{cm}^3$, and the coefficient of apparent expansion is $\gamma_{\text{app}} = 1.6 \times 10^{-4}\ \text{K}^{-1}$.

(b) Calculate the total temperature shift (ΔT) recorded across the afternoon observation interval: $\Delta T = 45°\text{C} - 15°\text{C} = 30°\text{C} = 30\ \text{K}$.

(c) Formulate the mathematical expression for the change in apparent volume (ΔV) of the expanding mercury: $\Delta V = V_0 \cdot \gamma_{\text{app}} \cdot \Delta T$.

(d) Substitute the parameters into the volumetric equation: $\Delta V = 0.25\ \text{cm}^3 \times (1.6 \times 10^{-4}\ \text{K}^{-1}) \times 30\ \text{K} = 0.0012\ \text{cm}^3$.

(e) The change in volume moves entirely into the uniform capillary tube, where it occupies a cylinder of length ΔL: $\Delta V = A \cdot \Delta L$, with $A = 1.2 \times 10^{-4}\ \text{cm}^2$.

(f) Solve for the linear displacement (ΔL): $\Delta L = \frac{\Delta V}{A} = \frac{0.0012\ \text{cm}^3}{1.2 \times 10^{-4}\ \text{cm}^2} = \frac{12 \times 10^{-4}}{1.2 \times 10^{-4}} = 10.0\ \text{cm}$.

Final Answer: The linear displacement of the mercury column is 10.0 cm.

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:
The total absolute pressure at any depth within a wet soil column depends on both the external atmospheric pressure overhead and the combined hydrostatic head contributed by the overlying layers of standing surface water and wet bulk soil.

Solution:

(a) Identify the pressure boundaries: the surface water layer is open to the atmosphere, so $P_{\text{atm}} = 1.013 \times 10^5$ Pa.

(b) Calculate the hydrostatic pressure contribution (P_{water}) from the 10 cm = 0.1 m layer of standing water maintained above the soil interface: $P_{\text{water}} = \rho_w \cdot g \cdot h_w = 1000 \text{ kg/m}^3 \times 10 \text{ m/s}^2 \times 0.1 \text{ m} = 1000$ Pa.

(c) Identify the target depth inside the core: the midpoint lies exactly 25 cm = 0.25 m below the soil-water boundary line.

(d) Calculate the pressure contribution (P_{soil}) from the wet soil layer using its bulk wet density ($\rho_{\text{soil}} = 1600 \text{ kg/m}^3$): $P_{\text{soil}} = \rho_{\text{soil}} \cdot g \cdot h_s = 1600 \text{ kg/m}^3 \times 10 \text{ m/s}^2 \times 0.25 \text{ m} = 4000$ Pa.

(e) Sum all independent pressure components to find the absolute pressure (P_{total}) at the midpoint: $P_{\text{total}} = P_{\text{atm}} + P_{\text{water}} + P_{\text{soil}}$.

(f) Substitute the values: $P_{\text{total}} = 101300 \text{ Pa} + 1000 \text{ Pa} + 4000 \text{ Pa} = 106300 \text{ Pa} = 1.063 \times 10^5$ Pa.

Final Answer: The total absolute pressure acting at the exact midpoint is $1.063 \times 10^5 Pa$.

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept:

Snell law states that for a medium with a continuously varying refractive index profile, the product of the local refractive index and the sine of the angle of refraction relative to the vertical normal remains constant at all depths.

Solution:

(a) State the generalized path invariant form of Snell law for stratified optical mediums: $\mu_{\text{air}} \cdot \sin\theta_{\text{air}} = \mu(z) \cdot \sin\theta_z$.

(b) Identify the initial conditions at the boundary entry point: air has a refractive index of $\mu_{\text{air}} = 1.0$, and the angle of incidence is $\theta_{\text{air}} = 45^\circ$.

(c) Calculate the constant value for this optical path: Constant $= 1.0 \times \sin 45^\circ = \frac{1}{\sqrt{2}} \approx 0.7071$.

(d) Use the given function to find the local refractive index (μ) of the solar pond at a depth of $z = 5.0$ m: $\mu(5) = \mu_0 + \alpha z = 1.33 + (0.02 \times 5.0) = 1.33 + 0.10 = 1.43$.

(e) Set up the equation to find the unknown angle of refraction (θ_z) at this depth layer: $1.43 \times \sin\theta_z = 0.7071$.

(f) Isolate the sine function: $\sin\theta_z = \frac{0.7071}{1.43} \approx 0.4945$. Taking the inverse function gives the vertical refraction angle: $\theta_z = \sin^{-1}(0.494)$.

Final Answer: The angle made by the light ray with the vertical is $\sin^{-1}(0.494)$.

Answer: (D)

Go Back to Question 20

Q21.

Solution

Concept:
A compound lever features multiple simple levers linked sequentially. The output mechanical force of the first lever acts as the direct input force for the second lever. The total ideal mechanical advantage of this combined network equals the product of the individual mechanical advantages of each lever stage.

Solution:

(a) Calculate the mechanical advantage (MA_1) of the first class-1 lever using its dimensional profiles: $MA_1 = \frac{\text{Effort Arm}_1}{\text{Load Arm}_1} = \frac{60\text{ cm}}{20\text{ cm}} = 3$.

(b) Determine the intermediate force (F_{link}) transferred through the mechanical coupling link using the manual entry force: $F_{\text{link}} = \text{Effort}_1 \times MA_1 = 80\text{ N} \times 3 = 240\text{ N}$.

(c) Calculate the mechanical advantage (MA_2) of the second class-1 lever stage: $MA_2 = \frac{\text{Effort Arm}_2}{\text{Load Arm}_2} = \frac{40\text{ cm}}{10\text{ cm}} = 4$.

(d) The intermediate link force now acts directly as the input driving force for this secondary lever step.

(e) Compute the final theoretical output cutting force (F_{output}) acting on the silage bale: $F_{\text{output}} = F_{\text{link}} \times MA_2 = 240\text{ N} \times 4 = 960\text{ N}$.

(f) Alternatively, the total system mechanical advantage is $MA_{\text{total}} = MA_1 \times MA_2 = 3 \times 4 = 12$. The final load equals $80\text{ N} \times 12 = 960\text{ N}$.

Final Answer: The theoretical output force cutting through the silage bale is 960 N.

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept:
The total thermal power transferred to a storage tank by a flowing liquid heat carrier depends on its mass flow rate, its specific heat capacity, and the absolute temperature drop experienced by the fluid as it passes through the internal heat exchanger tube.
Solution:

(a) Find the internal cross-sectional area (A) of the collection section pipe using its given diameter ($d = 2.0$ cm $= 0.02$ m): $A = \frac{\pi}{4} \cdot d^2 = \frac{\pi}{4} \times (0.02)^2 = 0.0001\pi$ m^2.

(b) Calculate the volumetric flow rate (Q) of the carrier fluid using its stable collection tube velocity ($v = 0.4$ m/s): $Q = A \cdot v = 0.0001\pi$ m$^2 \times 0.4$ m/s $= 0.00004\pi$ m^3/s.

(c) Convert the volumetric flow into a mass flow rate ($\dot{m}$) using the carrier fluid density ($\rho = 900$ kg/m^3): $\dot{m} = \rho \cdot Q = 900 \times 0.00004\pi = 0.036\pi$ kg/s ≈ 0.1131 kg/s.

(d) Formulate the thermal heat transfer rate equation using the fluid specific heat ($c = 3200$ J/kg $\cdot$ K) and the observed temperature drop ($\Delta T = 12°$C): Power $= \dot{m} \cdot c \cdot \Delta T$.

(e) Substitute the calculated values into the formula: Power $= 0.1131$ kg/s $\times$ 3200 J/kg $\cdot$ K $\times$ 12°C $= 4342.8$ W.

(f) Convert this absolute wattage value into kilowatts to match the options: Power ≈ 4.34 kW.

Final Answer: The rate of heat transfer to the water tank is 4.34 kW.

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept:
Static equilibrium requires both the total vertical upward forces to match the downward weights and the sum of all directional moments taken about any point along the rigid timber beam to equal zero.

Solution:

(a) Represent the beam as a rigid line of length 6 m. The uniform timber mass (m_b = 120 kg) creates a downward structural weight (W_b = 1200 N) acting exactly at its geometric center, 3 m from either support.

(b) The technician (m_t = 80 kg) exerts a concentrated downward force (W_t = 800 N) at a distance of 1.5 m from the left concrete pillar.

(c) Let R_L and R_R represent the upward reaction forces generated at the left and right support pillars, respectively.

(d) Take rotational moments about the right pillar support point to find R_L: $\sum M_R = 0 \implies R_L \times 6 = W_t \times (6 - 1.5) + W_b \times (6 - 3)$.

(e) Substitute the parameters and solve: $6R_L = (800 \times 4.5) + (1200 \times 3) = 3600 + 3600 = 7200$ N. This yields $R_L = 1200$ N.

(f) Use vertical force balance to find the remaining reaction force: $R_L + R_R = W_t + W_b \implies 1200 + R_R = 800 + 1200$, which gives $R_R = 800$ N.

(g) Compute the final ratio of the left support force to the right support force: $\frac{R_L}{R_R} = \frac{1200}{800} = \frac{3}{2}$.

Final Answer: The ratio of the upward reaction forces generated at the left support pillar to that at the right support pillar is 3 : 2.

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept:
A capacitor stores electrostatic potential energy within the electric field setup between its conductive surfaces. The total energy stored depends directly on the capacitance value of the structure and varies quadratically with the electrical potential difference applied across its electrodes.
Solution:

(a) Identify the parameters given for the coaxial insect trap: the grid assembly capacitance is $C = 150 \text{ pF} = 150 \times 10^{-12}$ F, and the peak operational potential difference is $V = 4.0$ kV = 4000 V.

(b) State the standard governing formula for the potential energy (U) stored inside an ideal capacitive electric field: $U = \frac{1}{2} \cdot C \cdot V^2$.

(c) Substitute the given values into the formula: $U = \frac{1}{2} \times (150 \times 10^{-12} \text{ F}) \times (4000 \text{ V})^2$.

(d) Square the potential difference term to simplify the calculation: $(4000)^2 = 1.6 \times 10^7 \text{ V}^2$.

(e) Multiply the remaining factors: $U = 0.5 \times 150 \times 10^{-12} \times 1.6 \times 10^7 = 75 \times 1.6 \times 10^{-5}$ J.

(f) Complete the multiplication to find the final absolute value: $U = 120 \times 10^{-5}$ J $= 1.2 \times 10^{-3}$ J. This energy discharges rapidly when an insect bridges the air gap.

Final Answer: The total electrical energy stored within the electric field of the trap mechanism is $1.2 \times 10^{-3} J$.

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:
For steady, incompressible, and frictionless fluid flow along a horizontal streamline, Bernoulli equation states that the sum of static pressure and dynamic pressure head remains constant. An increase in flow velocity must produce a corresponding drop in local static pressure.

Solution:

(a) State the classic horizontal Bernoulli equation linking the air stream states before and after passing through the falling paddy grain column: $P_1 + \frac{1}{2}\rho_a v_1^2 = P_2 + \frac{1}{2}\rho_a v_2^2$.

(b) Rearrange the mathematical terms to express the absolute magnitude of the static pressure drop ($\Delta P = P_1 - P_2$) across the bed: $\Delta P = \frac{1}{2}\rho_a \cdot (v_2^2 - v_1^2)$.

(c) Identify the given physical parameters: the heated air density is $\rho_a = 1.15$ kg/m^3, the initial velocity is $v_1 = 2$ m/s, and the exit velocity is $v_2 = 6$ m/s.

(d) Substitute these values into the velocity squared difference term: $v_2^2 - v_1^2 = 6^2 - 2^2 = 36 - 4 = 32$ m^2/s^2.

(e) Calculate the final pressure drop value: $\Delta P = \frac{1}{2} \times 1.15$ kg/m$^3 \times 32$ m^2/s$^2 = 1.15 \times 16 = 18.4$ Pa.

(f) Therefore, the constriction and velocity shift across the moving grain matrix creates a net pressure drop of exactly 18.4 Pa.

Final Answer: The magnitude of the pressure drop experienced by the air stream is 18.4 Pa.

Answer: (A)

Go Back to Question 25

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	B	3	D	4	A	5	A
6	C	7	B	8	A	9	A	10	C
11	A	12	A	13	A	14	A	15	B
16	C	17	A	18	B	19	A	20	D
21	C	22	B	23	C	24	A	25	A